

Modeling the alcoholic fermentation of cocoa by a selected yeast strain

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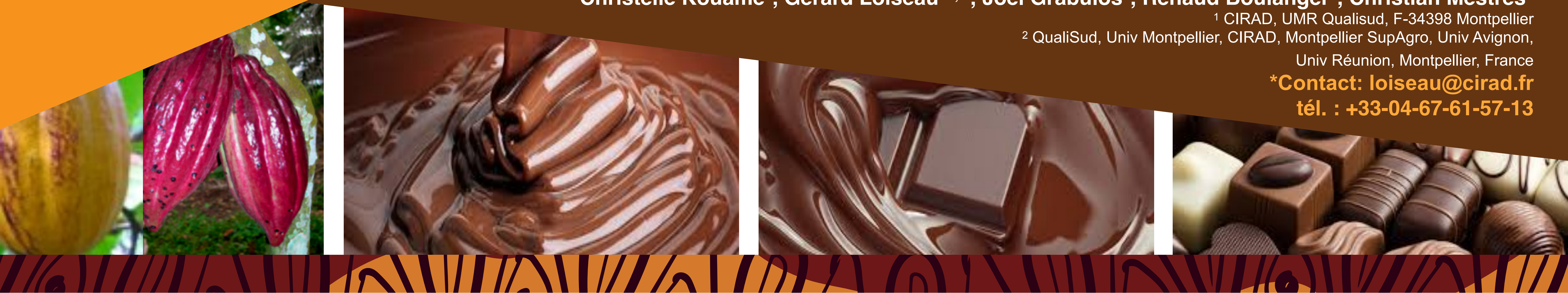
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CHOCOLATE is a pleasure-food consumed mainly for its aromatic quality directly related to that of the fermented and dried cocoa beans. The fermentation of the beans is a key step led by a wild microflora, poorly controlled, that sometimes leads to beans of undesirable quality. Its smooth running depends on multiple factors (Figure 1).

To control the quality of the beans, a mathematical model of alcoholic fermentation has been developed; it can be used to predict and optimize the behavior of a yeast strain according to the fermentation control parameters (inoculum level, T ° C, pH , PO₂).

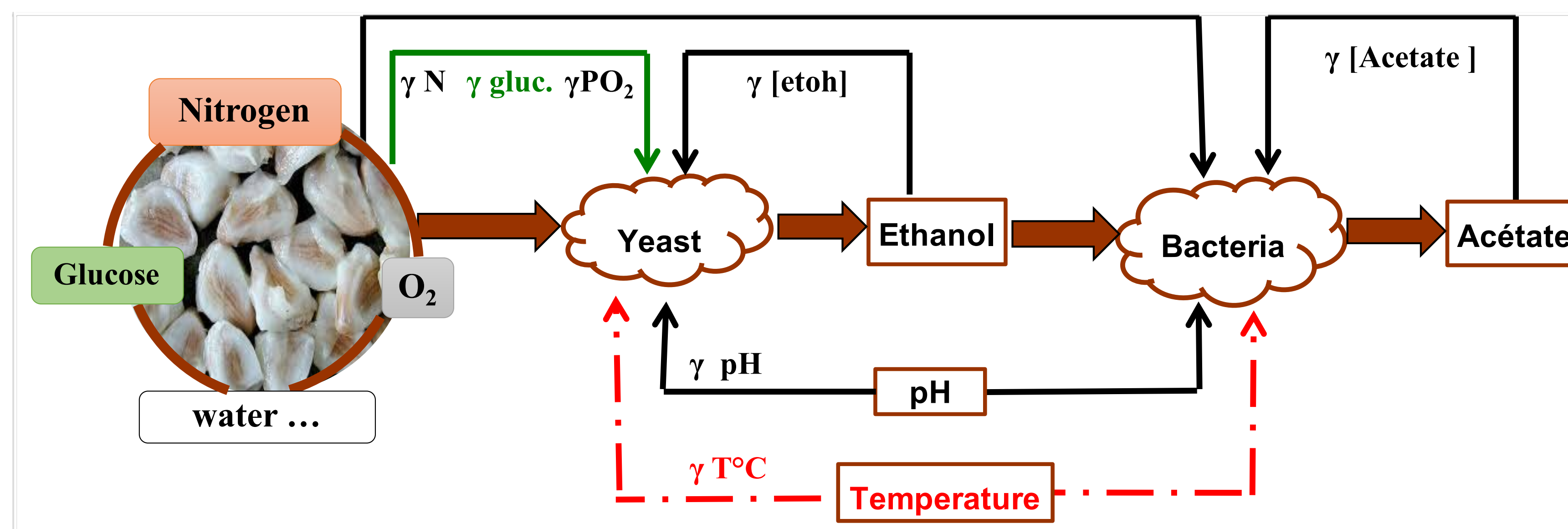


Figure 1. Schematic representation of bean fermentation.

Experimental approach

The growth of a *S. cerevisiae* strain (LM, Lallemand) was modeled by mobilizing the Rosso primary model (Eq.1) and the gamma concept (Eq.2). The parameters of the models were determined by growing LM in synthetic liquid medium, by varying the parameters independently. The model was implemented under Matlab-Simulink and two validations mimicking the natural fermentation conditions (pH, temperature profile, initial glucose content) were performed.

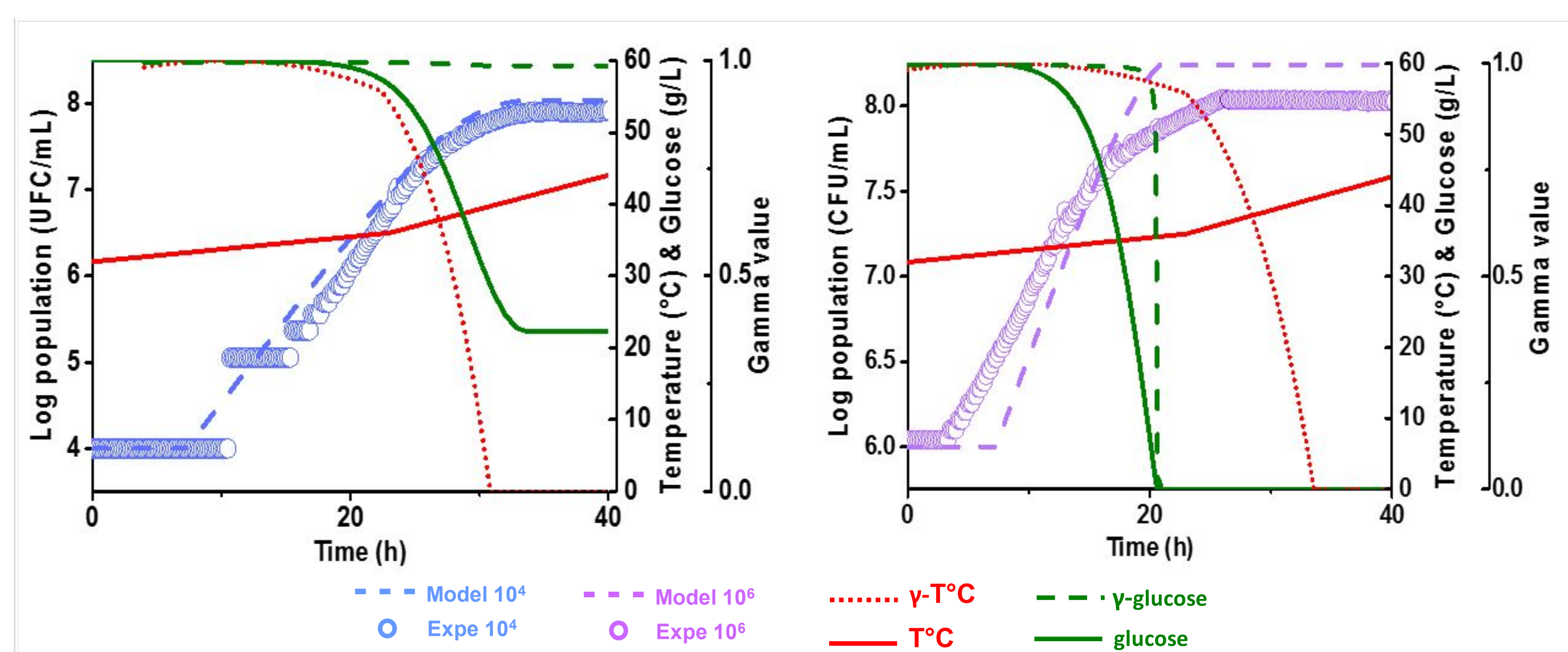
$$\text{Equation 1 : } dNt / dt = 0 \quad \text{si } t \leq \lambda \quad dNt / dt = \mu_{max} Nt (1 - Nt / N_{max}) \quad \text{si } t \geq \lambda$$

$$\text{Equation 2 : } \mu_{max} = \mu_{opt} \cdot \gamma T^{\circ}C \cdot \gamma pH \cdot \gamma [Gluc] \cdot \gamma [Etoh] \cdot \gamma [Azote] \cdot \gamma PO_2 \cdot \gamma [Acétate].$$

avec $0 < \gamma < 1$

Results: modeling yeast growth in "real" conditions

- Model predicts LM growth and growth arrest quite well.
- Inoculation at 10⁴ CFU/mL: when the temperature reaches 41°C, the γ-temperature drops to 0, and the growth of LM stops. There is still glucose in the environment.
- Inoculation at 10⁶ CFU/mL: the growth stops when the glucose level and γ-glucose reaches 0 (≈ 20h); there is no more glucose in the medium. The Tmax is reached later ≈ 35h.



Conclusion

- A mechanistic model predicts yeast growth during cocoa fermentation.
- The model predicts growth cessation depending on inoculation level.
- For low inoculation level, yeast growth stops with increased temperature of cocoa.
- For high inoculation level, depletion of glucose stops yeast growth.
- The model explains that depending on the quality of the raw material (glucose content), the conditions of inoculation and temperature maintenance, the quality of the cocoa will vary.
- The model is a tool to define the inoculation level of yeast for cocoa fermentation.

References

- Rosso *et al.*, 1995. Convenient model to describe the combined effects of temperature and pH on microbial growth. Appl. Environ. Microbiol. 61, 610–616.
- Zwietering *et al.*, 1993. A decision support system for prediction of microbial spoilage in foods. J. Ind. Microbiol. Biotechnol. 12, 324–329

